Forward π^0 Production in DIS at HERA

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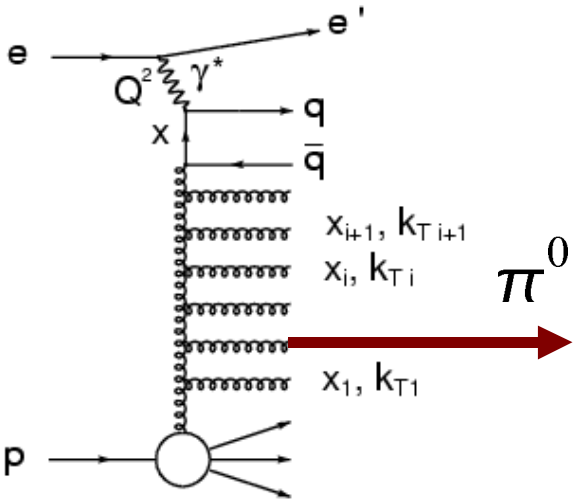
- Physics motivation
- Identification of π^0
- Results:
  - forward π^0 differential cross sections
  - characteristics of hadronic final state
- Conclusions

Physics motivation

test of QCD dynamics at low x



$$k_T^{\pi^0} \approx Q^2$$ → Suppress DGLAP evolution

$$x_{\pi^0} = \frac{E_{\pi^0}}{E_p} \gg x_B$$ → Enhance phase space for BFKL

DGLAP : resums terms $\sim \alpha_S \log Q^2$
strong ordering of parton k_T

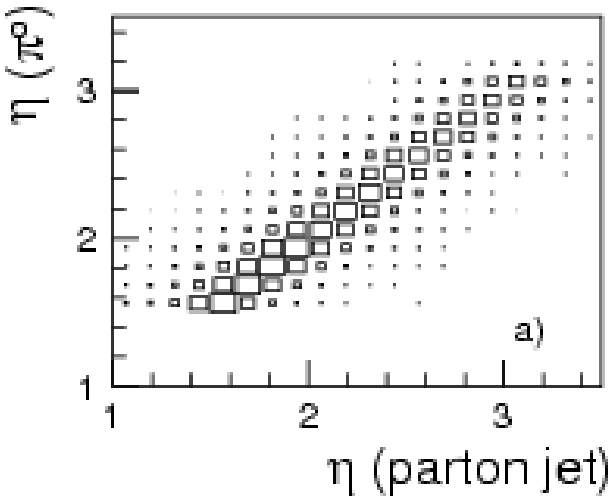
CCFM : initial state angular ordering
interpolates DGLAP / BFKL

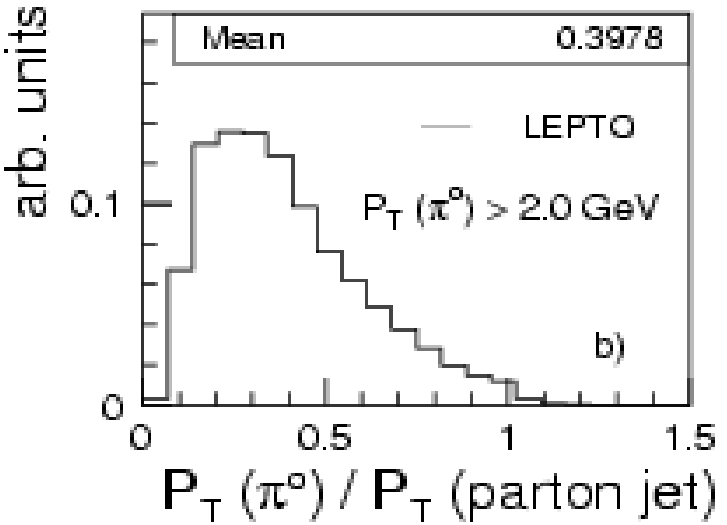
BFKL : resums terms $\sim \alpha_S \log 1/x$
no k_T ordering

HERA : test of QCD dynamics at low x

- $F_2(x,Q^2)$ measurements
- Heavy quark production in DIS
- Forward jet /particle production in DIS

high transverse momentum forward jet / particles sensitive to underlying parton dynamics





BFKL signatures at HERA

high E_T forward particle production in DIS ($k_T^{\pi^0} \approx Q^2, x_{\pi^0} \gg x_B$)

➔ refined version of the forward jet production (idea of Mueller, 1991)

➔ forward jet identified by its energetic fragmentation product

jet measurements

– ambigiuties of jet finding algorithms

– experimentally difficult in in the very forward region

+ higher rates

forward particle detection

+ single particle detection

+ identification possible in the most forward region (π^0)

– suppression of the rate

– fragmentation effects more significant

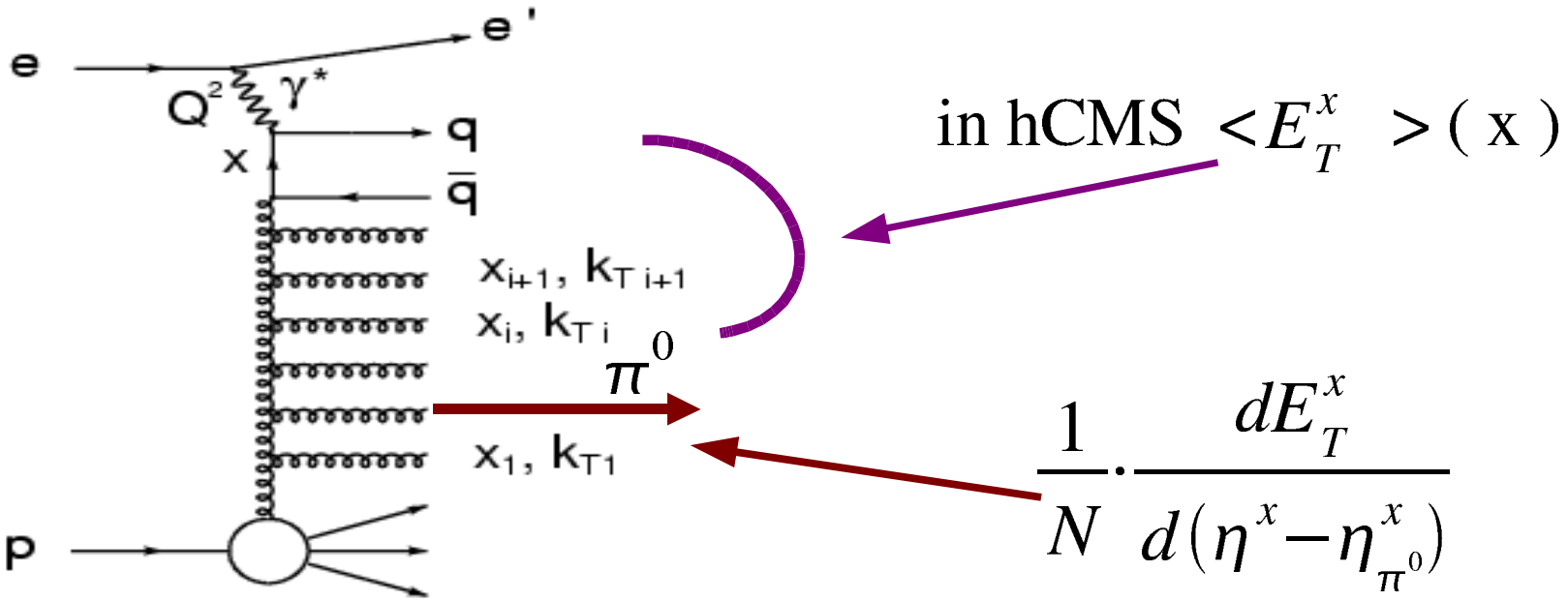
(comp. with models)

Goals of the new analysis of the forward π^0

- H1 Forward π^0–Meson Production at HERA ,Phys.Lett.B462 (1999) 440
- with increased statistics (factor 3.5) more differential distributions are possible
- investigation of the additional characteristics of the hadronic final state :

  A) transverse energy flow around π^0 direction

  B) average transverse energy as a function of x



Selection of data

$$e + P \longrightarrow e + \pi^0 + X$$

DIS sample

$2.0 < Q^2 < 70.0\ GeV^2$

$0.1 < y < 0.6$

x down to 10^{-5}

π^0 selection

$5^o < \Theta_\pi < 25^o$ forward region

$p_{T,\pi}^{x} > 2.5\ GeV$ high pt (hCMS)

$x_\pi = \frac{E_\pi}{E_p} > 0.01$ high energy

high energy ($E_\pi > 8.0$ GeV) $\pi^0 \longrightarrow 2\gamma$ reconstructed as
one electromagnetic cluster
in the finely segmented
H1 LAr calorimeter

Reconstruction of invariant mass of π^0 not applicable

→ based on Monte Carlo analysis of
the shower shape of the energy deposition

Identification of π^0 mesons

main experimental challenge → high particle / energy densities in the forward region

overlap of π^0 and charged pions induced clusters

H1 Liquid Argon calorimeter :

forward region – very fine granularity, cell size 3.5 x 3.5 cm^2

em section – 4 longitudinal segments, 20 –25 radiation lengths X_0

hadronic section – ~7 absorption lengths

detailed analysis of longitudinal and lateral shower shapes possible

π^0 identification : efficiency ~ 45 %

purity ~ 80 %

other sources of high energy photons:

prompt photon production – negligible

data corrected for the influence of η – meson production

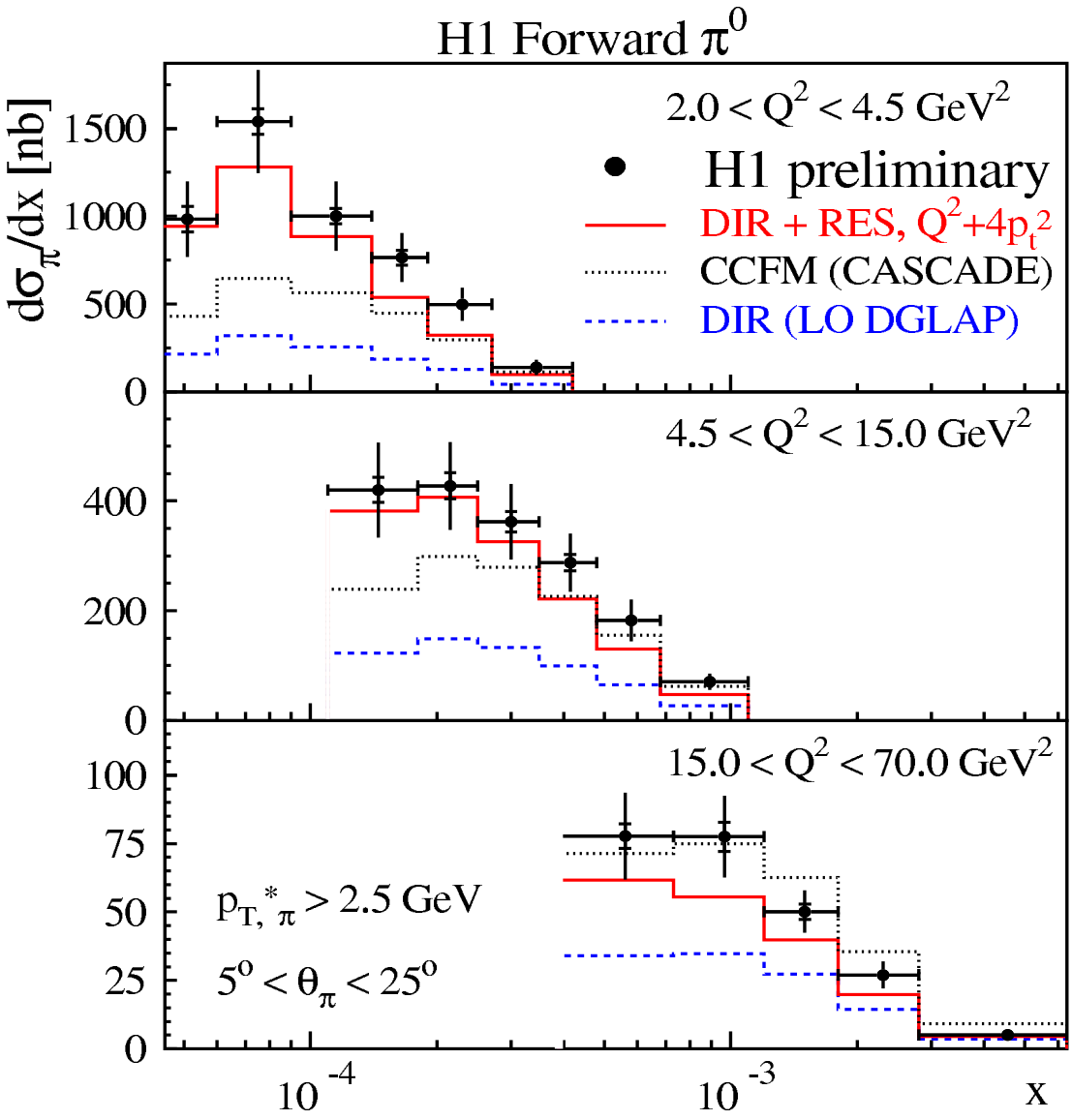
Results:

- Inclusive forward π^0 cross sections $\frac{d\sigma_\pi}{dx}$ and $\frac{d\sigma_\pi}{dp^x_{T,\pi}}$ in different regions of Q^2
- Distributions of transverse energy flow

Data corrected for : detector effects and influence of QED radiation
(bin–by–bin unfolding)

Measurement uncertainties :	E_T flow	x–section
➔ em energy scale (SPACAL)	1–2 %	5 %
➔ em energy scale (LAr)		5–10 %
➔ hadronic energy scale (LAr)	4 %	
➔ model depend.of detector correction	10–15 %	10–15 %
➔ variation of π^0 selection / identification	5–10 %	5–10 %
➔ luminosity determination		1.5 %

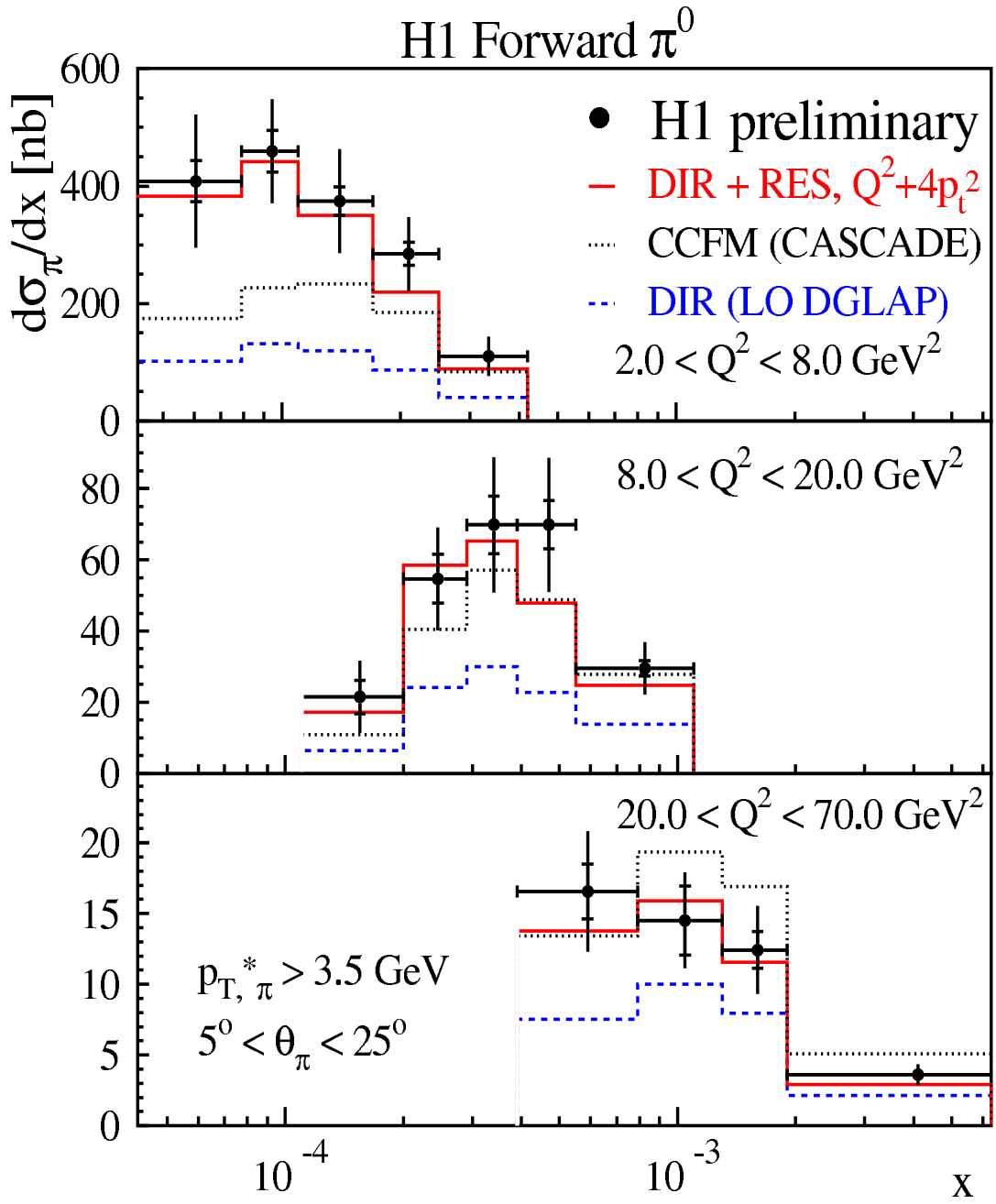
Results: $d\sigma_\pi/dx$ ($p^*_{T,\pi} > 2.5$ GeV)



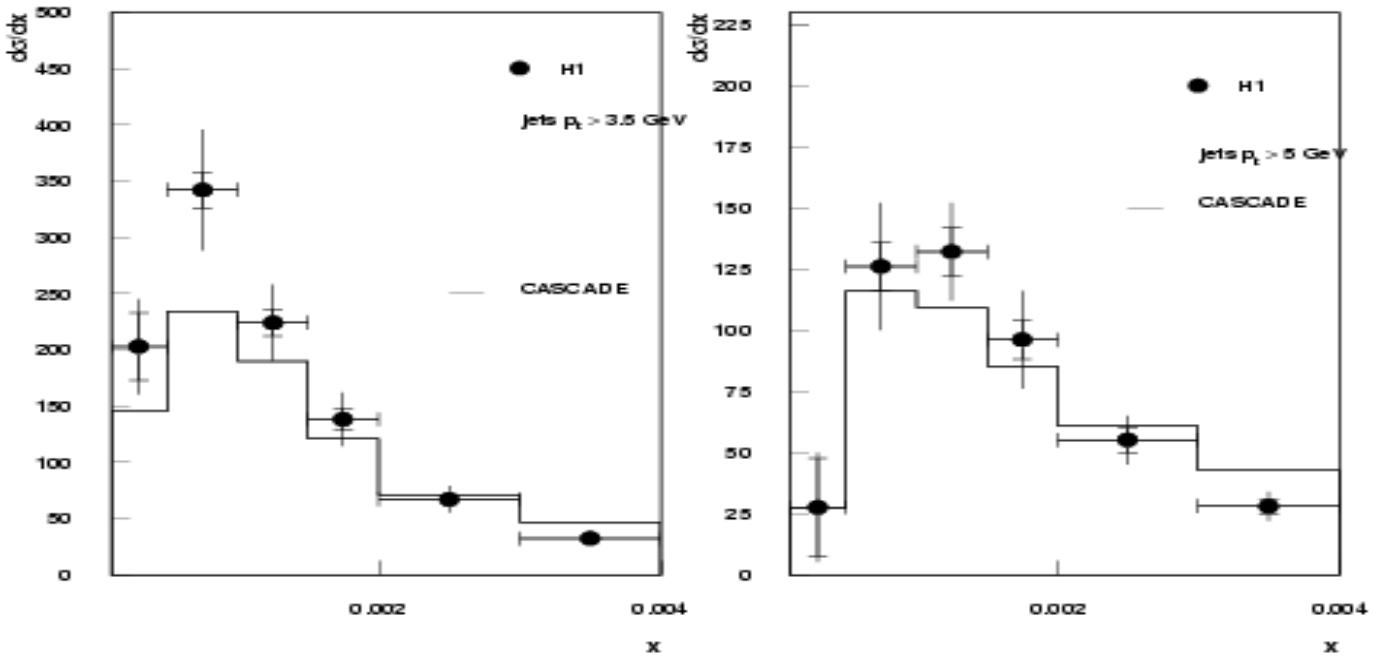
Reasonable description by RAPGAP(DIR+RES) with resolved photon contribution (provided scale is $Q^2 + 4p_T^2$).

CCFM (CASCADE) below the data for $Q^2 < 15.0\ GeV^2$.

Results: $d\sigma_\pi/dx$ ($p^*_{T,\pi} > 3.5$ GeV)

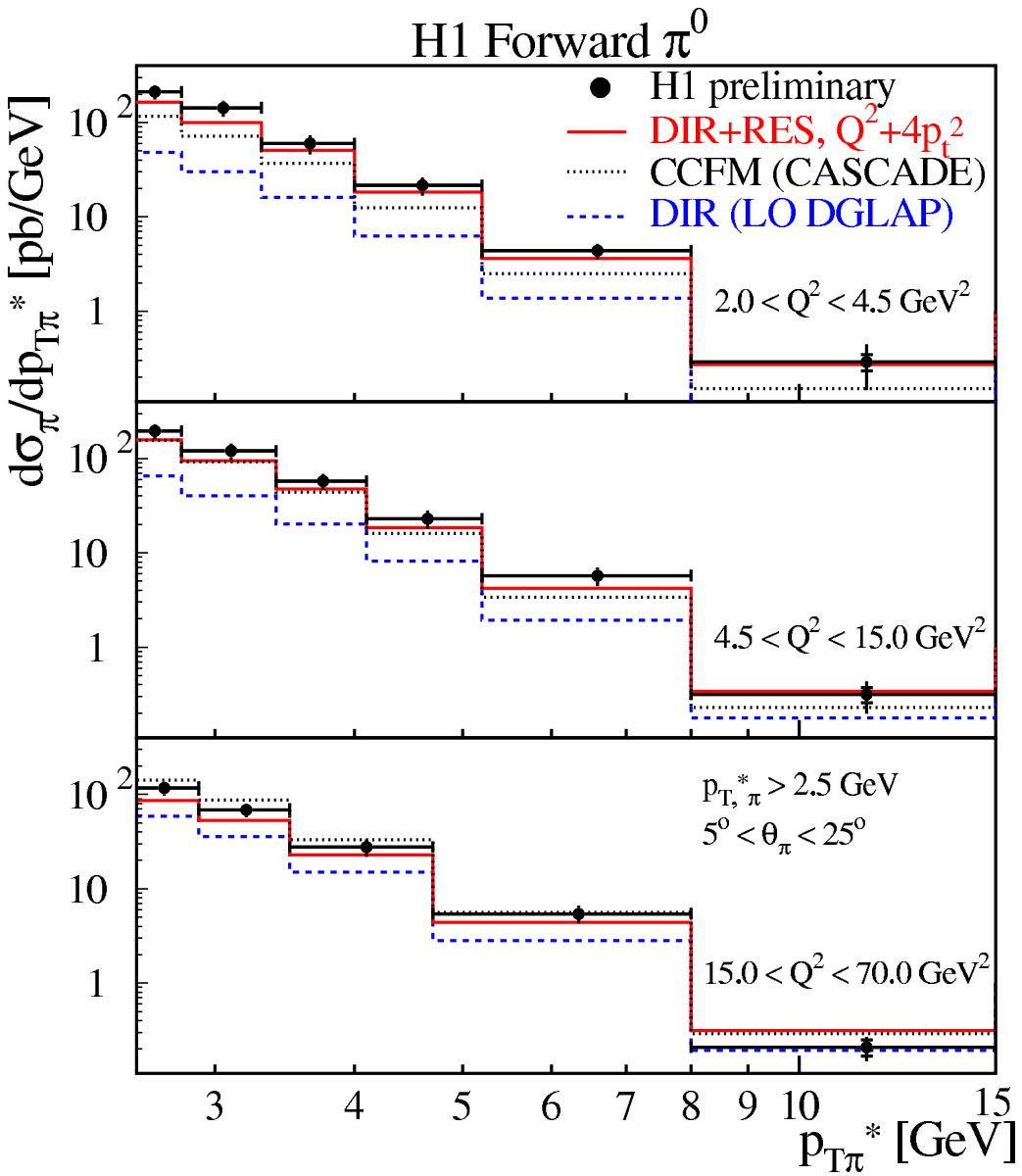


CASCADE (CCFM) – predictions for hadronic final state



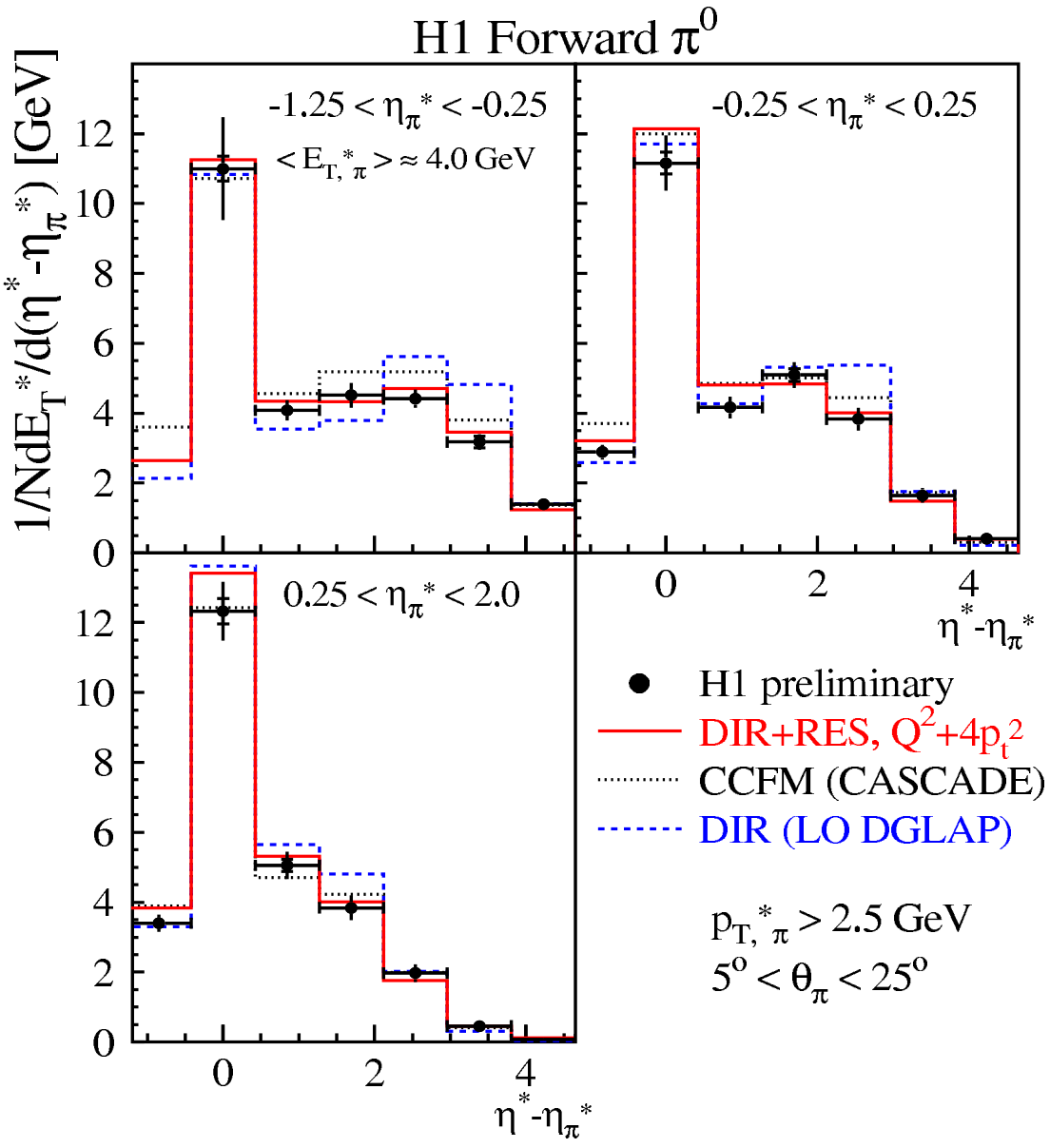
The cross section for forward jet production obtained from CASCADE, as a function of x, for different cuts in p_T compared to H1 data (DESY 00–151)

Results: $d\sigma_\pi/dp^*_{T,\pi}$ ($p^*_{T,\pi} > 2.5$ GeV)



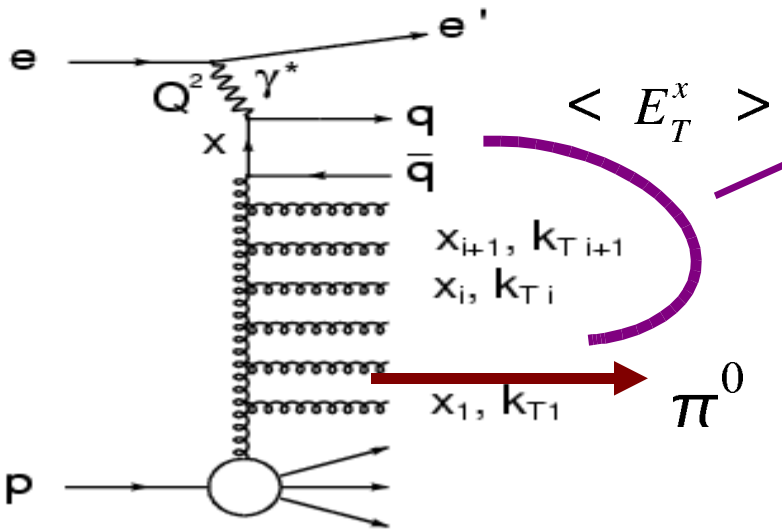
The same relation between the data and MC models observed in the whole range of $p^*_{T,\pi}$.

Results: Transverse energy flow ($p^*_{T,\pi} > 2.5$ GeV)

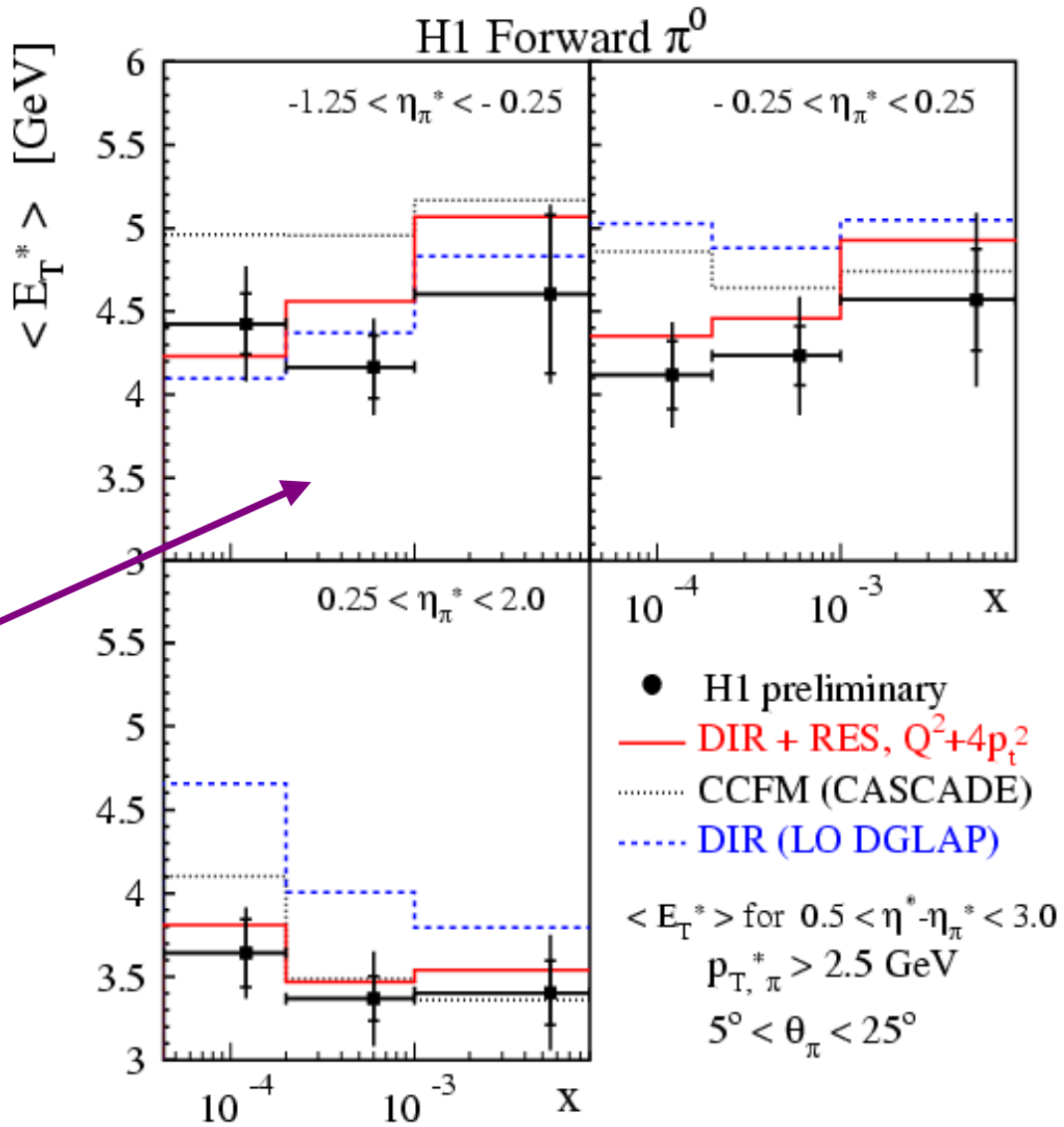


Transverse energy flow around π^0 direction reflects how the transverse momentum of the jet is compensated along the ladder.

$< E_T^x >$ vs. x



$< E_T^x >$



Mean transverse energy along the ladder above the jet is flat.

Conclusions

- New high statistics measurements of forward π^0 differential cross sections as a function of x and p_T
- Investigation of the associated transverse energy flow
- Point–like photon with DGLAP evolution fails to describe the cross section and the associated transverse energy flow
- Inclusion of the resolved photon component allows considerable improvement of the description of the data
- CCFM evolution model fails to describe the cross section in contrast to situation in forward jet production – fragmentation effect ?